

SATELLITE SOUND BROADCAST PROPAGATION STUDIES AND MEASUREMENTS

Wolfhard J. Vogel and Geoffrey W. Torrence

Electrical Engineering Research Laboratory
The University of Texas at Austin
10100 Burnet Rd., Austin, TX, 78758

Abstract--Satellite Sound Broadcasting is an attractive satellite application. Before regulatory decisions can be made in 1992, the propagation effects encountered have to be characterized. The Electrical Engineering Research Laboratory has nearly completed a system which will allow amplitude measurements to be made over 10 MHz bandwidths in the 800 to 1800 MHz frequency range. The system uses transmissions from a transportable tower, and reception inside buildings or in the shadow of trees or utility poles. The goal is to derive propagation models for use by systems engineers who are about to design satellite broadcast systems.

1. Introduction

The advance of fiber-optics technology has helped to focus future development of satellite services into areas where satellites are uniquely competitive. One of these preferred satellite applications is the broadcasting of high-quality sound for stationary or mobile reception by listeners using low-cost, consumer-grade receivers. Before such services can be provided, however, the political hurdles of spectrum allocation have to be surmounted and the technical questions of standardization for world-wide compatibility have to be resolved. In order to arrive at an optimal system design, efficient in the use of our scarce spectral resources, affordable both to the broadcaster and the listener, and providing predictable performance, the propagation effects to which the service is subjected have to be characterized.

Consequently, the objective of the research project described in this contribution is to make basic propagation measurements for direct Satellite Sound Broadcasting Service (henceforth referred to as SSBS). The data obtained should allow the development of propagation models to be used by communications engineers designing the operational systems. Such models shall describe the effects of shadowing and multipath propagation on SSBS receivers operating in a specified environment, such as inside commercial or residential buildings of various construction and also in the shadow of trees or utility poles as might be encountered by transporting or mobile listeners.

Many studies have already been undertaken, concentrating on digital techniques (Miller, 1988; Levey, 1988) and estimation propagation effects (Golshan and Vaisnys, 1990) for a hypothetical SSBS system.

The current window of potential SSBS frequencies was opened at the World Administrative Radio Conference dealing with the geostationary satellite orbit (WARC/ORB-88, non-geostationary orbits for SSBS are also under consideration) to include frequencies from 500 MHz to 3 GHz; a definite allocation will probably be made on the same forum in 1992. The study of propagation effects presented here is limited in the sense that (1) measurements will be performed in the frequency sub-range from 800 MHz to 1800 MHz, (2) amplitude characteristics only will be obtained, and (3) for the lack of a suitable satellite the transmitter will be mounted atop a transportable tower.

2. Experiment Description

In the following we give a description of our measurement plans for SSBS. Included are a sketch of a typical measurement setup, a block diagram of the measurement system, specifications of the measurement system, an explanation of our measurement strategy, and a description of typical measurement locations.

2.1 The Measurement Setup

The measurement system is self-contained and based around our LMSS van. The mobility of this design allows us to measure at any location of our choice, as depicted in Figure 1. Visible are (a) the van, (b) a transmitter tower which is mounted to the van and which supports the transmitter amplifier and antenna, (c) an obstacle, such as a tree or building, the effects of which on the propagation of the signal are to be determined, and (d) the receiver antenna, which connects to the receiver and data acquisition equipment in the van through a long cable.

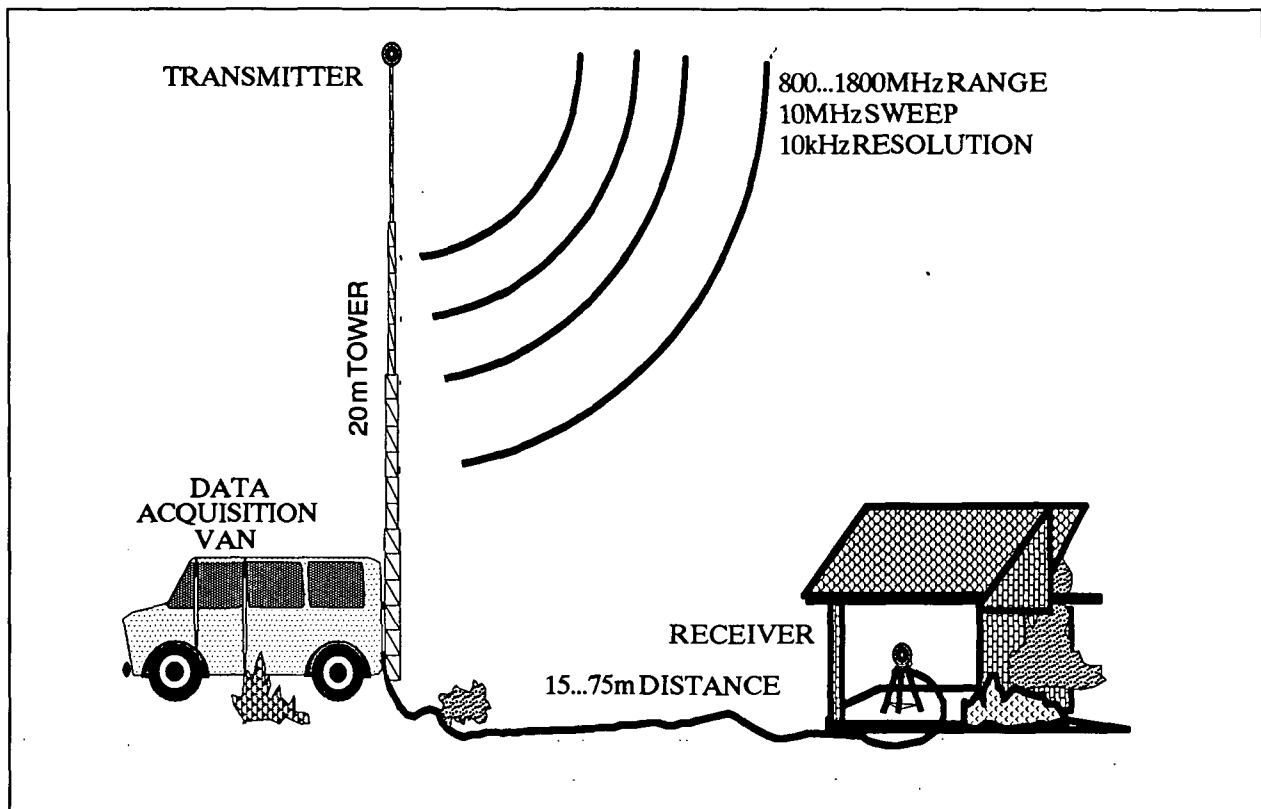


Figure 1: A typical scenario of SSBS propagation measurements in a building.

A typical scenario has the van parked outside of a building or in front of a tree. The tower is cranked up, elevating the circularly polarized transmitter antenna (140° half-power beamwidth) to a height of 20 m above ground. The antenna is pointed with a 30° to 45° depression angle towards the receiver area to be examined. In order to eliminate reflections from the aluminum tower, an absorbing shield is installed just below the antenna. The signal from the transmitter in the van is fed through a cable to the top of the tower, amplified to about 10 mW, and radiated towards the receiver. The receiver front end consists of an antenna and a low-noise amplifier. It is connected to the van through a cable

of about 75 m length. At the measurement location, the receiving front end is mounted to a non-conducting linear positioner which allows the antenna to be moved in small increments over about a 1 m range. The positioner can be adjusted for movement along any direction.

2.2 The Measurement System

Major components of the measurement system shown in Figure 2 are a Tektronix 2756P spectrum analyzer, a Hewlett-Packard 8662A synthesized signal generator, a PC with an IEEE-488 interface controlled by National Instruments LabWindows software, and a frequency converter built by EERL. The PC controls the instruments and displays and stores the data taken. The spectrum analyzer is set to a center frequency between 800 and 1800 MHz with a total frequency span of 10 MHz and a resolution bandwidth of 10 kHz. In this mode, one sweep takes about 5 seconds from the time it has started to the time the 1000 data points are stored on disk. The transmitter frequency is generated by mixing with the first local oscillator of the spectrum analyzer, thus slaving the transmitter to the spectrum analyzer as a tracking generator. The frequency conversion utilizes the synthesized signal generator.

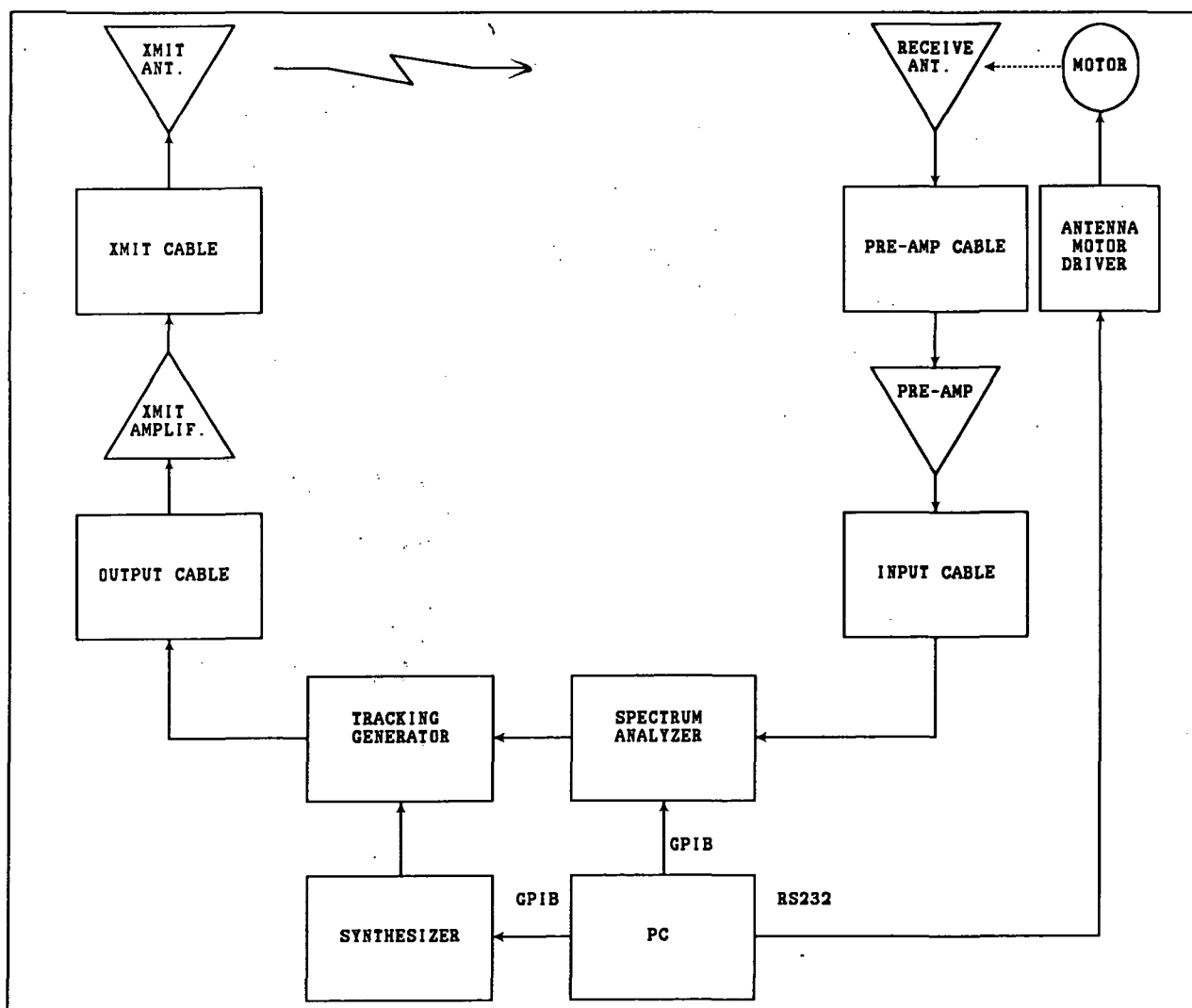


Figure 2: A block diagram of the SSBS measurement system.

2.3 Specifications

The pertinent specifications of the measurement system have been summarized in Table 1. Several different receiving antennas will be used in order to explore the sensitivity of the received signal levels to polarization and antenna size.

Frequency Coverage:	800 to 1800 MHz
Frequency Span:	10 MHz or 0 Hz
Frequency Resolution:	10 kHz
Trmt. Polarization:	RHCP Cavity Backed Spiral
Recv. Polarization:	RHCP Cavity Backed Spiral LHCP Cavity Backed Spiral Disk Cone (Linear Pol.) additional t.b.d.
Typical SNR:	45 dB at 1.5 GHz
Elevation angle range:	15° to 60°

Table 1: SSBS Propagation Measurement System Specifications

2.4 Measurement Strategy and Software

The measurement strategy is concerned with how the data are to be taken. One relevant concern is the presence of radio interference from transmitters within the test window of the spectrum analyzer. The severity of the interference depends very much on the location of the measurements (i.e. city or rural area), the time of day, and the particular center frequency chosen. Spectral surveying has shown that many frequencies can be selected where interference would be of concern only intermittently. For this reason, after tuning to a relatively clear 10 MHz channel near a frequency of interest, each data scan will be preceded and followed by a scan with our transmitter turned off. Any 10 kHz channels with signals present in either of these scans will be marked as invalid for the bracketed scan.

The receiving antenna positioner will be placed in the area to be measured and oriented as desired. At each position of the receiving antenna, scans can be taken at several center frequencies across the coverage of the system (maybe about 200 MHz apart), then the experiment controller will move the receiving antenna about 2.5 cm and repeat the process. This will produce data of path loss as a function of frequency and of location. To get information about the temporal variation of the signal level, scans can either be repeated or the system can operate at a fixed frequency (non-scanning) without moving the receiver.

The software for the PC is designed to run in the National Instrument LabWindows program development environment, where small sub-programs, or modules, are written and debugged using graphical interfaces called panels. Also, extensive use is made of the LabWindows internal functions controlling the graphics display, file handling, array processing, and the IEEE-488 and RS232 interfaces.

The modules are logically arranged in a bottom-up approach, [Figure 3] starting with LabWindows internal functions. At the lowest accessible level are modules controlling a specific hardware instrument, followed by the mid-level module which implements data acquisition procedures, and finally the top-level module which controls the sequence of data acquisition. The top-(main-) module receives instructions and outputs data via a set of files. The instruction file is written by a separate small program which must easily interact with

the operator, and thus must be outside of the LabWindows environment. Each of these levels will now be explained in more detail.

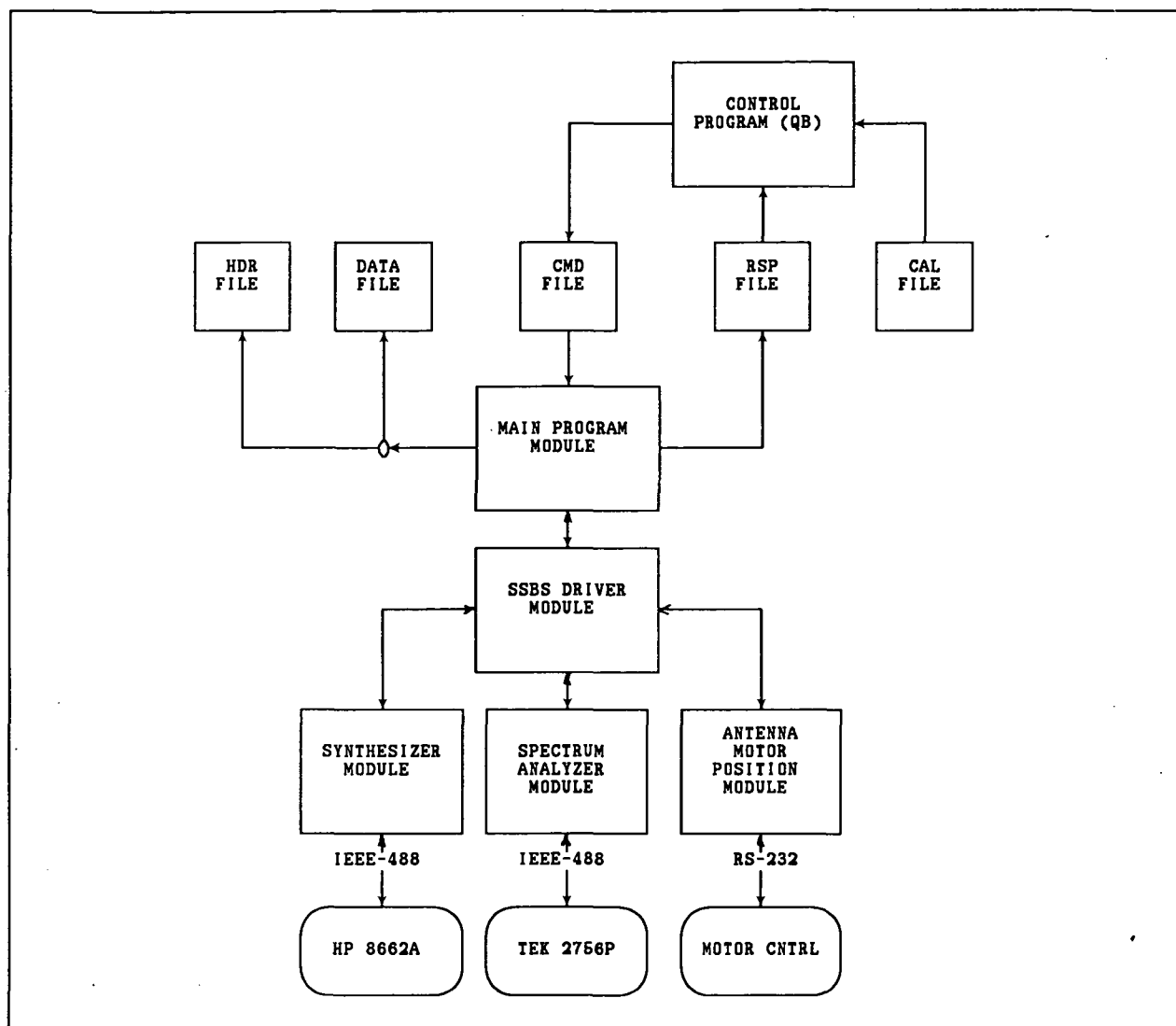


Figure 3: Software Organization for SSBS Measurements

LabWindows Functions: LabWindows implements a subset of the BASIC programming language which is upwardly compatible with Microsoft QuickBasic, which means that the final debugged program modules can all be compiled and linked with QuickBasic. In addition, LabWindows supplies as external libraries all the functions necessary to control the IEEE-488 and RS-232 interfaces, the graphics display and file handling on the PC, and many formatting and array processing functions. All of these libraries, as well as the LabWindows programming conventions and style were used as much as possible as the foundation of the data acquisition program.

HP 8662A Synthesizer Module: Only the basic frequency and amplitude control functions have been implemented as subroutines. The initialization routine does extensive checking to make sure the instrument is responding properly. Because software/hardware interactions are prone to many problems, all of the subroutines include many checks on proper operation.

TEK 2756P Spectrum Analyzer Module: A majority of the functions have been implemented as subroutines. As with the Synthesizer module, the initialization routine does extensive error checking. Control functions, such as frequency range and pre-detection bandwidth, are available. The data is retrieved as a 1000 element integer array scaled to the x-y display coordinates, and a set of conversion factors which are used to transform the array into real numbers scaled to dBm vs. MHz.

Antenna Positioner Module: The antenna positioner, although quite simple compared to either of the above, is implemented as a separate instrument module for programming consistency. It is connected to the PC via the RS232 interface, so initializing the "instrument" is really opening a serial port. Motor motion is controlled by sending single ASCII characters which are decoded as in/out and start/stop. The "instrument" responds with single ASCII character decoded to represent revolutions of the drive screw or hitting one of the end of travel switches. As an example, calling the subroutine AntMotor.advance(3) will send the character for start-forward, wait until three revolution characters have been received, and then send the motor stop character. Receiving an end of travel character would be an error.

SSBS Driver Module: This mid-level module lumps together many of the lower level functions from the above modules into sequences useful for our specific SSBS experiment, in contrast to the above modules which were written to be as general as possible. For example, calling the subroutine GPIB.init not only initializes the three instruments but also sets them into the configuration for this experiment. As another example, calling the subroutine DSSB.err.check checks all of the error flags of all the instruments and libraries and halts the program gracefully with a diagnostic message if an error occurs.

A secondary purpose of this module is to convey parameters to the various instruments and to the display. When a program consists of a number of modules, passing variables from module to module is easy, but must be done very carefully. This program has subroutines specifically for this purpose, although most of them are quite simple.

The main purpose of this module is to implement the procedures, or sequences of functions, used in data acquisition. The two elementary procedures are:

F-Sweep: a single sweep in frequency over an arbitrary 10 MHz, resulting in 1000 samples at 10 kHz spacing.

F-Mono: at an arbitrary time, sample in time for 10 seconds, resulting in 1000 samples at 10 milliseconds per sample.

In both cases, a) the video filter is OFF, b) all samples are average value, c) the vertical scale is 10 dB per division, and d) the tracking generator is ON.

A variation, or special case, of the two basic procedures are 'Pre-' and 'Post-', where the tracking generator is OFF, and the sample is taken with PEAK values. Thus, for example, an F-Sweep measures the strength of the signal received from the tracking generator, and a Post-F-Sweep measures the background noise or RFI level. Also a Pre-F-Mono plus a Post-F-Mono total 10 seconds.

The next two higher level procedures are a combination of the above basic procedures. They accomplish the RFI excised frequency sweep and the temporal stability assessment, respectively.

Frequency Sweep: a three step procedure of

- 1) Pre-F-Sweep
- 2) F-Sweep
- 3) Post-F-Sweep.

If any points in either Pre- or Post- F-Sweeps are above the value of threshold, then the corresponding point in the F-Sweep is blanked (set to an illegal value). Only the F-Sweep array (step 2) is saved to a file.

F-Mono Sweep: a four step procedure of

- 1) Pre-F-Sweep
- 2) Pre-F-Mono
- 3) F-Mono
- 4) Post-F-Mono.

After step 1, the point of lowest RFI is chosen, based on a sliding 10 pixel average. Steps 2 and 4 give the baseline noise, and peak values over a threshold value indicate RFI. Finally, step 3 gives the peak, RMS, and average values of signal stability. Only the statistics are saved to a file.

The reading of the command file and the writing of the data files are also implemented in subroutines.

Main Program Module: The data acquisition is orchestrated in this module, and is the only module where the procedures are not fixed. The main procedures are as follows.

Frequency Scan: a set of Frequency Sweeps taken in the range of 0.8 to 1.8 GHz. The number of scans and the frequency of each scan are determined from a study of the local RFI environment, and are loaded from the command file and are recorded with the data.

P-Scan: a set of Frequency Scans taken at intervals along the mechanical arm. The number of positions and the spacing between positions are loaded from the command file and are recorded with the data.

Position Scan: a two, four, or six step procedure of

- 1) F-Mono-Sweep
- 2) X-axis P-Scan
- 3) F-Mono-Sweep
- 4) Y-axis P-Scan
- 5) F-Mono-Sweep
- 6) Z-axis P-Scan

A Position Scan results in a set of data files containing a header, statistics, and all the F-Sweep data. If all three axes are done, it takes approximately 1 hour to complete.

Control Program: The Control program is the operator interface. The operator will input the position of the receive antenna relative to the transmit antenna (X,Y,Z), the polarization of the receive antenna, and a comment. The other experiment parameters such as number of frequencies, number of positions, etc., will probably remain unchanged from nominal; but, as an option, everything can be set. For a given position (X,Y,Z), the control program will interpolate from the table and find the free space loss. This value in turn will

be used to normalize the path loss measured by the main program. When all is set, the Command File is written, and the main program is run. After the main program completes, a Response file is written, and the Control program is again run. This time, the results are first displayed, and if all is okay, the process starts over again.

2.5 Measurement Locations

In order to calibrate the system, measurements will be made in an open field of the received line-of-sight signal level as a function of distance from the transmitter over the full range of center frequencies. All the measurements through trees and into buildings will be referred to this reference level. The stability of the system should allow absolute calibration to within about 1 dB, with much better relative calibration. It will be of importance, therefore, to accurately determine the transmitter-receiver distance during the experiment. Prospective measurement sites are:

- a) Our laboratory building (single story concrete block exterior, wood frame interior, concrete on steel roof construction),
- b) A modern concrete tilt-wall office building,
- c) A multi-level parking garage (concrete/steel),
- d) Trees at Balcones Research Center (Oak, Pecan, etc.) and at a nearby State Park (Pine),
- e) Houses of varying construction (with/without aluminum heat shield, mobile home).

3 Analysis

The data will be analyzed to determine the spectral, spatial, and temporal variations of signal levels due to multi-path propagation and shadowing. Measurement parameters will be the type of receiving antenna used, the presence or not of a person near the receiving antenna, the measurement location and type of shadowing obstacle. Results will include the mean and variance of the signal attenuation as well as correlation distances in the spectral, spatial, and temporal domain.

4 RFI Tests

The RFI environment at our laboratory was tested over the full frequency range from 800 to 1800 MHz and with a 1 MHz bandwidth, in a maximum-hold mode for 20 seconds, 120 seconds and 45 minutes integration time, respectively. Comparing the spectra, it was found that the proposed mode of operation, i.e. acquisition of each 5 second data sweep sandwiched into transmissionless sweeps and excision of any active interference, will be successful in most of the band most of the time.

References

- Golshan, N. and Vaisnys, A., "Satellite Sound Broadcasting System, Portable Reception," in Proc. of 13th AIAA ICSSC, Los Angeles, CA, Part 1, pp. 186- 204, March 11-15
- Miller, J. E., "Application of Coding and Diversity to UHF Satellite Sound Broadcasting Systems" IEEE Transactions on Broadcasting, Vol. 34, No. 4, pp.465-475, December 1988
- Levey, R. J. (Ed.), "Advanced Digital Techniques for UHF Satellite Sound Broadcasting" Published by the EBU Technical Center, Bruxelles, Belgium, August 1988